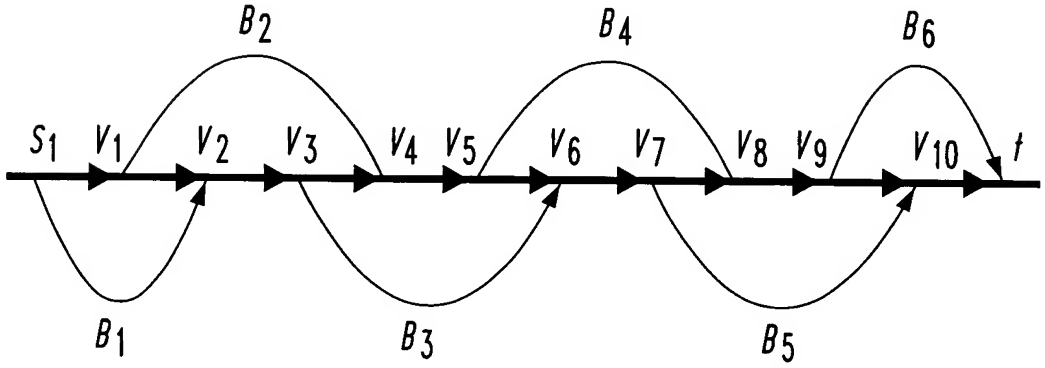

FIG. 1

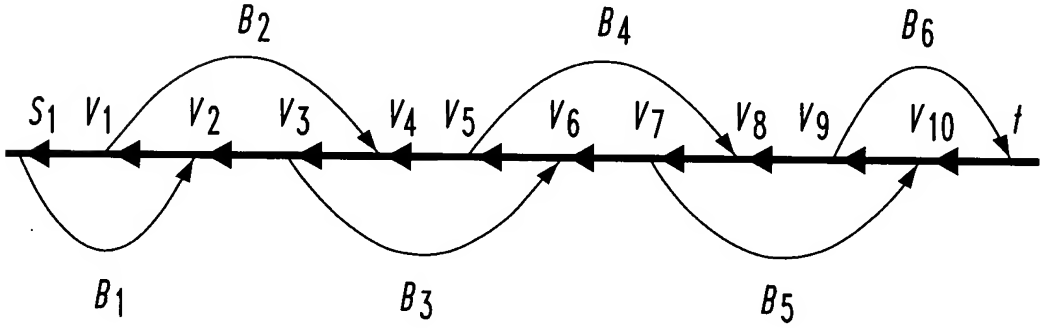

FIG. 2

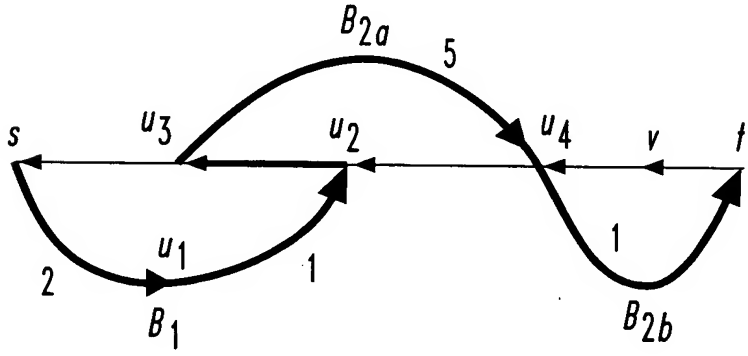

FIG. 3

FIG. 4

Algorithm PP ($G(V,E), \hat{\mathcal{P}}, \hat{d}, U$)

parameters:

$G(V,E)$ - network,

$\{d_l, c_l\}_{l \in E}$ - delays and costs of the network links,

$\hat{\mathcal{P}} = \{s = v_0, v_1, ..., t = v_n\}$ - QoS path,

$\hat{d}$- delay constraint,

U- the upper bound on the cost of $\mathcal{R}$.

```
1  Δ ← d̂ − D(P̂)
2  E' ← E
3  for each link l = (v_i, v_{i+1}) ∈ P̂ do
4     E' ← E' \ {(v_i, v_{i+1}) ∈ P̂}
5     E' ← E' ∪ {(v_{i+1}, v_i) ∈ P̂}, c_{(v_{i+1}, v_i)} ← 0
6  for all v_i ∈ V do
7     D_{v_i}[0] ← ∞
8  D_s[0] ← 0
9  for c = 1, 2, ..., U do
10    for each v_j ∈ V in order such that v_j is before v_{j'} if v_j is a successor of v_{j'} in P̂ do
11       D_{v_j}[c] ← D_{v_j}[c − 1]
12       for each link l = (v_i, v_j) ∈ E' do
13          RELAX(l(v_i, v_j), c, Δ)
14    if  D_t[c] ≤ D(P̂) then
15       determine walk W by backtracking
16       return W.
17 return FAIL
```

CONTINUED ON SHT 3/8

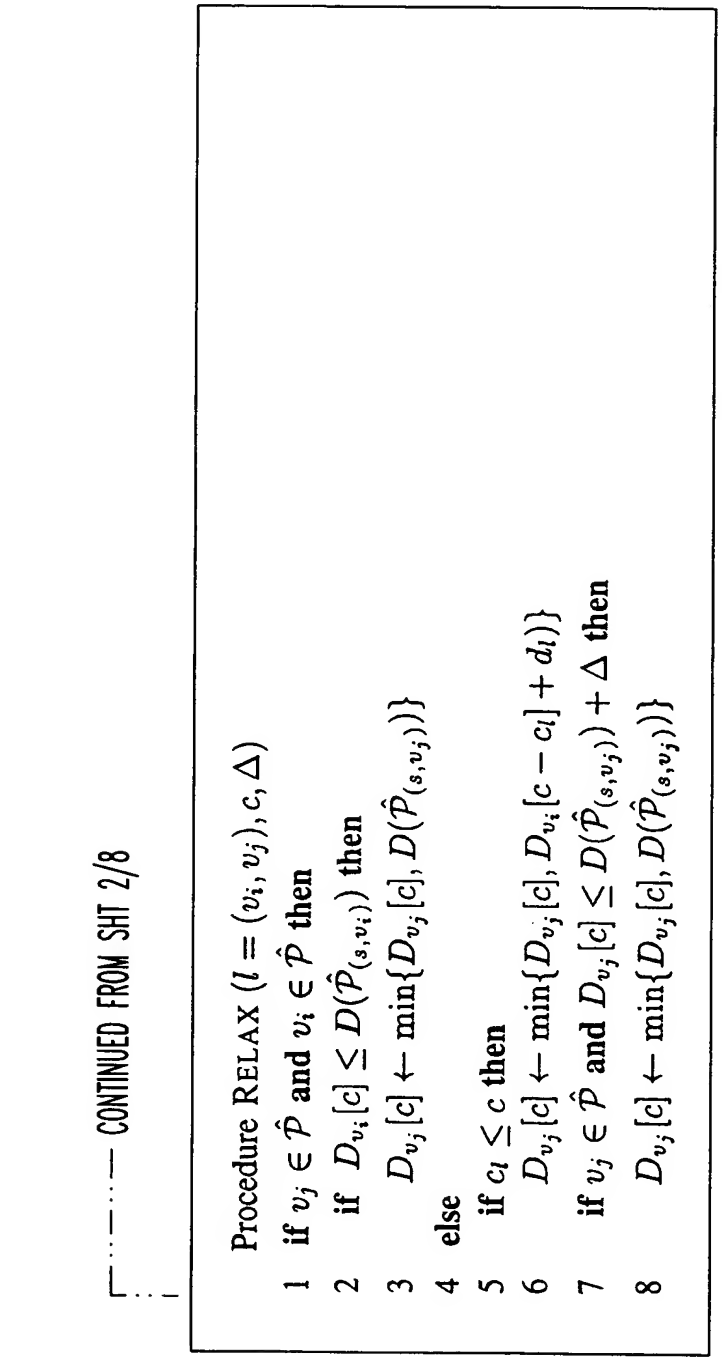

FIG. 4

FIG. 5

Algorithm RT ($G(V,E), \hat{\mathcal{P}}, \hat{d}, \varepsilon$)

parameters:

$G(V,E)$ - network

$\hat{\mathcal{P}} = \{s = v_1, v_2, ..., t = v_n\}$ - QoS path,

$\hat{d}$- delay constraint

ε- approximation ratio

1 $L, U \leftarrow$BOUND$(G(V,E), \hat{\mathcal{P}}, \hat{d})$
2 **do**
3 $B \leftarrow \sqrt{L \cdot U}$
4 **if** TEST$(G(V,E), \hat{\mathcal{P}}, \hat{d}, B, \varepsilon)$ returns YES **then**
5 $L \leftarrow B$
6 **else**
7 $U \leftarrow 2 \cdot B$
8 **until** $U/L \leq 8$.
9 $\mathcal{W} \leftarrow$SCALE$(G(V,E), \hat{\mathcal{P}}, \hat{d}, L, U, \varepsilon)$
10 **return** the restoration topology that corresponds to $\mathcal{W}$.

Procedure SCALE$(G(V,E), \hat{\mathcal{P}}, \hat{d}, L, U, \varepsilon)$

1 $S \leftarrow \frac{L\varepsilon}{2N}$
2 **for** each link $l \in E$ **do**
3 $c'_l \leftarrow \lfloor \frac{c_l}{S} \rfloor + 1$
4 $\tilde{U} \leftarrow \lfloor \frac{U}{S} \rfloor + 2N$
5 **return** PP$(G(V,E), \{d_l, c'_l\}_{l \in E}, \hat{\mathcal{P}}, \hat{d}, \tilde{U})$

CONTINUED ON SHT 5/8

FIG. 5

CONTINUED FROM SHT 4/8

```
Procedure TEST(G(V,E), P̂, d̂, B)
1  Apply Procedure SCALE for (G(V,E), P̂, d̂, B, B, 2)
2  if Algorithm SCALE returned FAIL then
3    return NO
4  else
5    return YES

Procedure BOUND(G(V,E), P̂, d̂)
1  let c^1 < c^2 < ··· < c^r the distinct costs values of the
   links.
2  low ← 1; high ← r
3  while low < high − 1
4    j ← ⌊(high + low)/2⌋
5    E' ← {l | c_l ≤ c^j}
6    set c_l ← 1 for each l ∈ E'
7    apply Algorithm PP on (G'(V,E'), P̂, d̂, 2N)
8    if Algorithm PP returned FAIL then
9      high ← j
10   else
11     low ← j
12 U ← 2N · c^high; L ← c^high;
13 return L, U;
```

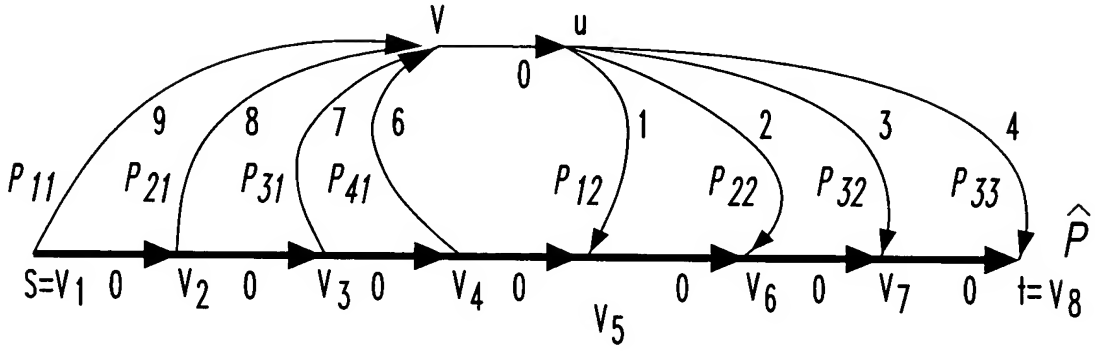

FIG. 6

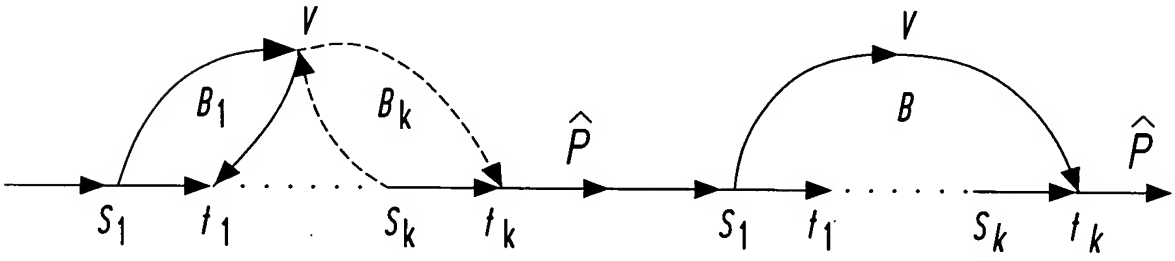

FIG. 7

FIG. 8

Algorithm DRT ($G(V,E), \hat{\mathcal{P}}, \hat{d}, \varepsilon$)

parameters:

$G(V,E)$ - network

$\hat{\mathcal{P}} = \{s = v_1, v_2, ..., t = v_n\}$ - QoS path,

$\hat{d}$- delay constraint

ε- approximation ratio

1 $\hat{d}' \leftarrow 2\hat{d} - D(\hat{\mathcal{P}})$
2 $L, U \leftarrow$BOUND$(G(V,E), \hat{\mathcal{P}}, \hat{d}')$
3 **do**
4 $B \leftarrow \sqrt{L \cdot U}$
5 Apply Procedure SCALE for $G(V,E), \hat{\mathcal{P}}, \hat{d}', B, B, \varepsilon)$
6 **if** Procedure SCALE return FAIL **then**
7 $L \leftarrow B$
8 **else**
9 Set $\mathcal{W}$ be the walk returned by Procedure SCALE
10 **if** $C(\mathcal{W}) \leq L$ **then**
11 **return** the restoration topology $\mathcal{R}$ that corresponds to $\mathcal{W}$.
12 **else**
13 $U \leftarrow 2 \cdot B$,
14 **until** $U/L \leq 8$.
15 Apply Procedure SCALE for $(G(V,E), \hat{\mathcal{P}}, \hat{d}', L, U, \varepsilon)$
16 **if** Procedure SCALE does not fail **then**
17 Set $\mathcal{W}$ be the walk returned by Procedure SCALE
18 **return** the restoration topology $\mathcal{R}$ that corresponds to $\mathcal{W}$.

FIG. 9

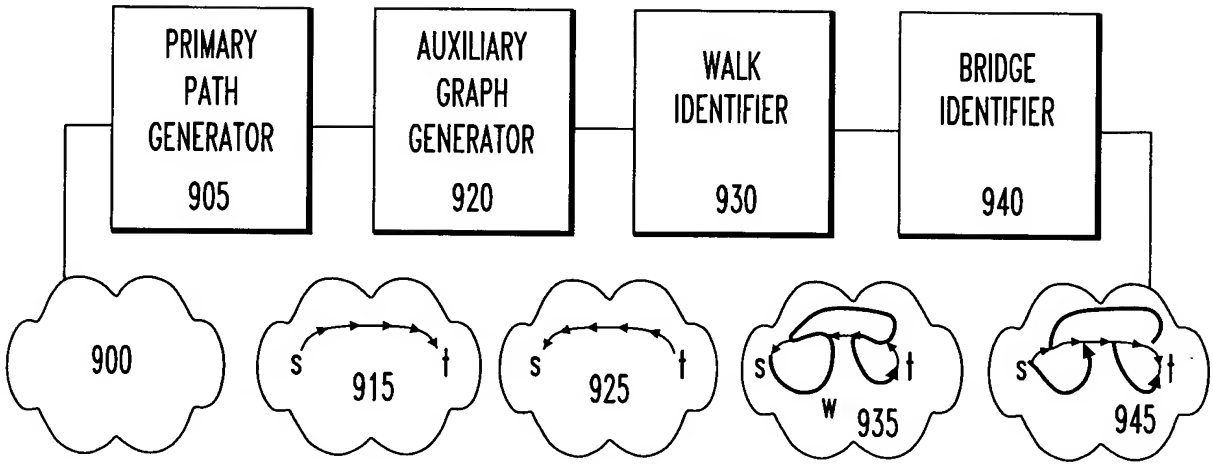

FIG. 10